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THE DEVELOPMENT OF ANIMATED FILMS TO FACILITATE CREATIVE SPACE PERCEPTION.

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THREE DIFFERENT METHODS OF TEACHING DESCRIPTIVE GEOMETRY WERE EVALUATED. AN ANALYSIS WAS MADE OF (1) THE ACHIEVEMENT OF 176 STUDENTS TAUGHT BY THE MULTIVIEW PROJECTION METHOD, (2) 172 STUDENTS TAUGHT BY THE PICTURE METHOD PLUS MULTIVIEW PROJECTION, AND (3) 188 STUDENTS TAUGHT BY THE FIRST TWO METHODS AND ANIMATED FILMS. THE BASES FOR ANALYSIS WERE DAILY WORK, DRAWING PLATES, QUIZZES, REVIEWS, WORKBOOKS, QUESTIONNAIRES, AND A FINAL EXAMINATION. STUDENTS AMONG THE THREE POPULATIONS WERE EQUIVALENT IN TERMS OF (1) PAST PERFORMANCES, (2) FIELD OF CONCENTRATION, AND (3) GENERAL ACADEMIC ABILITY. NO SIGNIFICANT DIFFERENCES IN OVERALL ACHIEVEMENT WERE CLEARLY DISCERNIBLE AMONG POPULATIONS. SEVEN RECOMMENDATIONS ARE OFFERED FOR FUTURE RESEARCH. (HB)

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THE DEVELOPMENT OF ANIMATED FILMS
TO FACILITATE CREATIVE SPACE PERCEPTION

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SUMMARY

To evaluate the effectiveness of three different methods of teaching Graphics II, the achievement of 176 students taught by the multi-view projection method, 172 students taught by the picture method plus multi-view projection, and 188 students taught by the picture method, plus multi-view projection, plus animated films was analyzed on the basis of daily work, plates, T-quizzes, reviews, workbook, an anonymous questionnaire, and a final examination. Students among all three populations were equivalent in terms of past performance, field of concentration, and general academic ability. The films, produced at Rensselaer, covered only the first six weeks of the course, but statistical results were processed and evaluated separately not only for the first six weeks but also for the remaining ten weeks, and for the entire semester.

No significant differences in over-all achievement were clearly discernible among the three populations. The differential effectiveness of the three methods of instruction may have been obscured by (a) reduction of lecture time for the population that was taught partly by films; (b) lesser demand in daily work on students of whom pictorial representation was not required, and, in this same population, greater demand for instructors' help, greater opportunity to obtain assistance from other students in daily work, and more intensive preparation by the instructors due to use of an unfamiliar text; and (c) insensitivity of the course requirements as evaluating instruments. These factors led to the following recommendations and comments concerning further study of the problem: (a) future research designs should insure that the use of newer educational media does not interfere with the adequate coverage of material in the lecture, (b) daily work requirements for all populations should be made equal, (c) instructors should pay active

attention to students' daily work, in all populations, with particular alertness to those who need but do not seek help, (d) the physical arrangement of classroom equipment should be as identical as possible for all populations, (e) maximum effort by instructors in the preparation of lectures should be assured, (f) over-all course requirements should be as rigorous as possible, and (g) more sensitive measurements of achievement than are provided by typical course requirements should be devised. In addition, it is suggested that future studies emphasize the process of motivating the student to "receive" information via newer media, rather than concentrate on the methodology of "transmitting" information which was the main concern of this investigation, as it has been of many others conducted elsewhere.

OBJECT AND SCOPE OF THE INVESTIGATION

The object of the investigation was to study the relative effectiveness of three methods of teaching Graphics II, a course in descriptive geometry taken by nearly all second-term, engineering freshmen at Rensselaer. This course is preceded by Graphics I, which emphasizes the art and some elementary theory of engineering drawing. Graphics II emphasizes the theory of the science of form.

The content of Graphics II is summarized in the following description from the Rensselaer Catalogue, 1961-62:

"Graphics II - The advanced theory of spatial arrangement using freehand picture sketches and instrumental orthographic layouts in the development of the thought process which involves the point, line, and plane, as well as single curved, double curved, and warped surfaces. Approximately one-third of the course shows applications of this theory to typical problems in the numerous fields of engineering, such as framing layouts, vector space diagramming, mining, fuselage problems, wire and tower layout, clearances, and surface representation with intersection and development. The applications are based on advanced theory, and require the aid of previously developed background material and dexterity of expression."

An important objective, implicit in the above description, is to help the student learn to "see" three-dimensional objects in space and to understand their spatial characteristics. The investigation tested three methods as means of accomplishing this objective. These were the multi-view projection method; the picture method, plus multi-view projection; and the picture method, plus multi-view projection, plus animated films. The first method is a traditional one, exemplified by the textbook Applied Descriptive Geometry by Frank M. Warner and Matthew McNeary; the second method was developed about ten years ago and is reflected in Descriptive Geometry - A Pictorial Approach by Harold Bartlett Howe; and the third is a new method, based on the pictorial approach, plus newly created films in which theoretical space concepts are visualized.

Initially, five animated films were produced as experimental materials necessary to the investigation. However, six films were used during the study, the additional one having been produced with Rensselaer funds prior to the experiment. It should be explained also that the first of the five films, produced for this study, had a long introduction. Subsequent to the investigation, this sequence was made into a separate film, Introduction To Spatial Concepts. In effect, then, six films resulted from the investigation. Including the one previously produced, seven films now exist as a series, covering the first half of Graphics II.

Although films were available only for the first six weeks of the course, statistical results were processed and evaluated separately not only for the first six weeks but also for the remaining ten weeks, and for the entire semester.

Production of the films began July 1, 1959 and continued until January 31, 1961. Classroom experimentation took place during Spring 1961 (February 6 through June 7). Results were evaluated during the period of June 13 through September 30, 1961.

PRODUCTION OF THE FILMS AS EXPERIMENTAL MATERIALS

In keeping with Rensselaer's philosophy of film production, the films created for this project were, in themselves, experimental both as to instructional design and filmic interpretation. The instructional design of each film was evolved to meet both the over-all objective of helping students to "see" and understand selected spatial concepts in their study of the science of form and the specific informational objective inherent in the content which it was desired that each film convey. It was believed that attainment of the over-all objective would result in films which would challenge the student to think deeply and creatively about the characteristics and relationships of three-dimensional objects in space; attainment of the specific informational objective of each film would involve the student in a communication process whereby content was dynamically presented and, it was hoped, actively rather than passively received. Filmic interpretation to implement these instructional designs relied heavily on animation, an approach which was experimental in the sense that inexpensive, little-used techniques were refined and developed to accommodate the specific demands imposed by the instructional design of each film.

The production of the films involved close co-operation between representatives of the Department of Engineering Drawing, who acted as content authorities, and personnel of the film production unit of Rensselaer's Office of Institutional Research, who were responsible for filmic interpretation and cinematography. This co-operation included all phases of production: prescripting and scripting activities, including storyboard preparation; construction of models and drawings; shooting; editing;

sound recording; workprint evaluation; and final editing. Answer prints were used for classroom experimentation, after which the films were revised slightly and release prints acquired. The films average 15-20 minutes in length; they are 16mm, in color, with voice-over narration.

The following titles, with notes on content, describe the films used in this investigation:

1. Points and Lines. The theory of line forming by the controlled displacement of a point. Space considerations related to straight and curved planar lines, with an introduction to the non-planar curved space line. (Produced at Rensselaer prior to this experiment.)
2. Planes. The generation of a plane surface by line control. Limited and unlimited plane areas with the location of points and lines on these areas. Aspects of planar surfaces related to various points of view.
3. Line and Plane Relationships - Part I. Parallel and perpendicular concepts in the spatial configuration of line positions.
4. Line and Plane Relationships - Part II. Space relationships of line and plane and plane and plane. Space concepts developed for viewing three-dimensional theoretical form. Limits of angular displacement to distinguish between apparent and true size values.
5. Revolutions. The rotation of line and plane. How rotation affects the angular displacement of parts or alters specific values as they pertain to the given theoretical configuration.
6. Vectors. Directed magnitudes such as forces, velocities, etc., represented by directed line segments. Resultant (or equilibrant) of vector space systems.

As stated previously, Points and Lines was produced prior to this investigation; likewise, the long introduction, originally part of Planes, was made into a separate film, Introduction to Spatial Concepts, subsequent to the experiment. This film will serve, in the future, as an introduction to the entire series. Each of the other films has, of course, an appropriately developed, short introductory sequence.

Each instructional design, evolved through scripting and storyboard preparation, posed problems of filmic interpretation and execution which

could be solved only through experimentation with production techniques. For example, using "step" drawings as the basis of animation materials was found, in Planes, to require unexpected precision in order to convey the theory involved. Therefore, for later films, models were constructed, coated with "glow" paint, and photographed in motion under ultra-violet light. This technique, sometimes used in combination with cells based on perspective drawings, was found to result in faster and less expensive production, with, it is believed, an increase in the technical quality of the presentations and in the impact of the information so visualized. At other times, multiplexing mirrors were used in filming animation effects from several models operating in synchronization. Additional production techniques included use of the split frame, the animation materials consisting of color transparencies of models for the pictorial part of the frame and black-and-white prints of multi-view projections of the models for the remaining part or parts of the frame. Colored overlays and other more conventional materials were also used where appropriate. The selection, refinement, and utilization of these techniques necessarily became a more ambitious part of the over-all investigation than was originally conceived.

Sample frames visualizing subject matter from the films may be found in Appendix B.

STANDARD INSTRUCTIONAL PROCEDURE

Graphics II is a one-semester course (two credit hours and six contact hours). Each class is held twice a week, each period lasting three hours. In the past, the three-hour period was devoted to a 50-minute lecture, followed by two hours of problem solution in the laboratory. Problem solution consists of problems in theory, generally referred to as "daily work," and application assignments, generally referred to as "plates." The daily work and the plates are graded separately. During problem solution, the students are permitted to seek help from the instructor and fellow students, and to consult their text and lecture notes.

At intervals the students are given examinations, referred to as "T-quizzes." During these, no help is available from any source. Averages based on daily work, plates, and T-quizzes are calculated at the end of 3, 6, and 12 weeks.

After completion of 12 weeks of instruction, six consecutive periods are devoted to problem solving exercises known as "reviews." Again, no help is available during these periods. No lectures are given during reviews; however, preceding each review, the previous period's exercises are returned, their contents explained, and the students' questions answered.

Prior to the end of the term, all students are required to submit their workbooks. These contain all the completed and corrected daily work, plates, and T-quizzes. A separate grade is given for the workbook.

The last day of the term is devoted to the final examination. This requirement, however, is waived for students who attain an A-grade average (on the A, B, C, D, F scale), based on grades in daily work, plates, T-quizzes, reviews, and workbook. For these students, A is recorded as the final grade in the course; for the remaining students, the final grade is calculated by inclusion of the grade in final examination.

EXPERIMENTAL PROCEDURE

Subjects

The experiment was conducted on all students registered in Graphics II in Spring 1961, with the exception of 14 students comprising the so-called "honors" section. The total number of subjects was 536. With very few exceptions, the subjects were students of engineering, in the second semester of their freshman year.

Treatments

Since the aim of the experiment was to compare three different methods of teaching, certain modifications were introduced in the Standard Instructional Procedure for different groups of students. The three methods, henceforth referred to as "treatments," are:

Treatment I - Multi-View Projection Method,

Treatment II - Picture Method, plus Multi-View Projection, and

Treatment III - Picture Method, plus Multi-View Projection, plus Animated Films.

The modifications in procedure for each of the three treatments are shown in Table 1.

TABLE 1. INSTRUCTIONAL PROCEDURE UNDER THE THREE TREATMENTS

	<u>Treatment I</u>	<u>Treatment II</u>	<u>Treatment III</u>
Text	Introduced for this experiment. Almost completely free of pictorial illustrations.	One used in recent years, with emphasis on pictorial representation of forms in space.	Same as II.
Lecture Period	50 minutes, without the aid of pictures.	50 minutes, with the aid of pictures.	Film: 20 min. Lect.: 30 min. with the aid of pictures.
Problem Solving	Pictorial representation <u>not</u> required.	Pictorial representation required.	Pictorial representation required.

Under Treatment III, division of the lecture period into "film" and "lecture" occurred only during the first six weeks of the term. No films were shown during the second six weeks, and the lecture lasted 50 minutes. Each film covered two days' assignment and was shown twice, during consecutive periods. The second showing covered the previous period's material and also introduced the student to the material with which he would be concerned in the current day's problem solving.

Controls

To accommodate the large enrollment in the course, the students were divided into five sections, meeting at four different times. (Enrollment in one of the time periods was sufficiently large to warrant its division into two sections.) The five sections are identified in Table 2 by arabic numerals, together with the times of meeting.

TABLE 2. WEEKLY PERIODS OF INSTRUCTION IN GRAPHICS II

<u>Section</u>	<u>Time of Meeting</u>
1	Tu. & Th., 8-11 a.m.
2	Tu. & Th., 8-11 a.m.
3	W. & F., 8-11 a.m.
4	M. & W., 2-5 p.m.
5	Tu. & Th. 2-5 p.m.

To preclude confounding of treatment effects with date and time of instruction, each section was divided into three groups for assignment to each of the three treatments. This division resulted in a total of fifteen groups, five under each of the three treatments.

To balance out the student variables, such as field of study and academic standing, a master plan for assigning students to treatments was developed prior to registration. According to the plan, each group of a particular section was to have about the same proportion of students majoring in a specified field. Furthermore, within any specified field, the

distribution of grades earned in Graphics I was to be uniform in the three groups.

The final distribution of students among treatments is shown in Table 3. In each cell the first number refers to the frequency and the second to the Graphics I average among students represented by the frequency, the grading based on the 4.0 system.

TABLE 3. DISTRIBUTION OF STUDENTS AMONG TREATMENTS

<u>Major</u>	<u>Treatment I</u>		<u>Treatment II</u>		<u>Treatment III</u>	
A.E.	23	2.57	16	2.69	24	2.58
Ch.E.	21	2.38	22	2.45	21	2.43
C.E.	9	2.22	9	2.56	9	2.56
E.E.	56	2.64	57	2.58	57	2.55
M.E.	17	2.65	16	2.56	21	2.55
Other	9	2.67	11	2.54	11	2.36
Undesignated	<u>41</u>	<u>2.39</u>	<u>41</u>	<u>2.27</u>	<u>45</u>	<u>2.40</u>
Total	176	2.52	172	2.50	188	2.49

As a test of equivalence among treatment populations, the distributions were compared by the chi-square method. This statistical technique depends on discrepancies between observed frequencies and theoretical frequencies derived from the horizontal and vertical totals. The chi-square value obtained (2.36, 12 degrees of freedom) yields a probability value (p) in excess of .99. The value of p as high as that obtained indicates that the discrepancies are less pronounced than one might expect by chance, and that the treatment populations may certainly be regarded as equivalent. As far as grade averages are concerned, these, in the column totals, are almost identical and do not warrant further statistical analysis.

To eliminate another source of confounding - the influence of the teacher - no instructor was permitted to teach more than one group under any one treatment. The distribution of instructors among the 15 groups is shown in Table 4, with cell entries being the code letters for the instructors.

TABLE 4. DISTRIBUTION OF INSTRUCTORS AMONG EXPERIMENTAL GROUPS

<u>Section</u>	<u>Tr. I</u>	<u>Tr. II</u>	<u>Tr. III</u>
1	E	B	D
2	A	C	F
3	G	E	B
4	B	A	C
5	C	D	A

In the table above, instructors A, B, and C taught under each of the three treatments; instructors D and E taught under two treatments; and instructors F and G taught under one treatment only. As will be seen later, the over-all treatment effects were checked periodically against results obtained from the symmetrically balanced groups, i.e., groups taught by instructors A, B, and C.

Evaluating Instruments

The student performance in the course was measured by instruments described in the paragraphs on Standard Instructional Procedure. Grades were assigned on a 4-point system for each of the following: (1) daily work, (2) plates, (3) T-quizzes, (4) reviews, (5) workbook, and (6) final examination. As mentioned earlier, the grades for the first three items were averaged after 3, 6, and 12 weeks. Instruments demanding independent performance were identical in all treatments within any one section but differed from section to section; these were T-quizzes, reviews, and final examination.

Statistical Analysis

The initial step in the analysis of results was to select the proper statistical approach. The original plan was to use analysis of variance, contingent on the expected equivalence of treatment populations and normal distribution of results.

As shown earlier, the expectancy of equivalence was fulfilled. This equivalence was further corroborated by the distributions of cumulative academic averages within treatments. The cumulative medians were, respectively, 3.43, 3.48, 3.46. The differences are not statistically significant. The normalcy of distribution, however, was not demonstrated. A plot made of the distribution of final averages showed a well-defined bi-modal trend. To test whether bi-modality in the final averages represented the cumulative effect of deviation from normalcy in individual groups, the chi-square method was applied to randomly selected groups. In this test, comparisons were made within each grade bracket between observed frequencies and those one might expect, were the distribution normal. In most instances, the discrepancies were too large to permit the assumption of normalcy. Accordingly, analysis of variance had to be rejected as the proper technique.

The alternatives to the analysis of variance, used subsequently, were the chi-square method and the so-called "median test." The latter is a special case of the chi-square method, having a distribution divided in only two categories, one above, the other below the population median. The use of the median test was necessitated by the fact that the chi-square method is sensitive not only to differences between medians but also to differences between distributions. When chi-square is small (and, consequently, p is large) it may be safely inferred that neither the medians nor the distributions differ significantly. On the other hand, if the chi-square is large, and p falls below some predetermined value, the median test may be used to determine whether the effect is due to differences between medians or between distributions. In the present study, the median test was used whenever the value of p fell below .05.

RESULTS

Treatment Effects

Table 5 shows the results of statistical analysis on several of the instruments discussed earlier. The cell entries are median scores. Differences between medians are regarded as significant if the p value is below .05. In every such instance the significance was confirmed by the median test.

TABLE 5. DISTRIBUTION OF MEDIAN SCORES ON EVALUATING INSTRUMENTS

<u>Instrument</u>	<u>Tr. I</u>	<u>Tr. II</u>	<u>Tr. III</u>	<u>p</u>
3-wk. grade	3.35	3.35	3.27	.05 < p < .10
6-wk. daily work grade	3.46	3.51	3.40	p < .001
" plates	3.38	3.31	3.35	p = .30
" T-quizzes	3.23	3.26	3.09	.20 < p < .30
" average	3.36	3.32	3.27	.05 < p < .10
12-wk. daily work grade	3.49	3.43	3.37	p < .001
" plates	3.35	3.30	3.31	p = .05
" T-quizzes	3.13	3.10	3.03	.70 < p < .80
" average	3.36	3.25	3.22	p = .01
Reviews	3.44	3.48	3.46	.50 < p < .70
Workbook	3.46	3.40	3.47	.02 < p < .05
Final exam (non-exempts)	3.17	3.21	3.26	.10 < p < .20
Final averages	3.36	3.30	3.30	p = .30

With the arbitrary criterion of significance of $p < .05$, the table shows that some differences between medians cannot be attributed to the operation of chance factors. These are differences between the medians of: (1) 6-wk. daily work grades, (2) 12-wk. daily work grades, (3) 12-wk. averages, and (4) workbook grades.

Of the several instruments listed in the table, the most valid criteria of evaluation are probably those in which the student is expected to perform without extraneous help. Such instruments, as indicated earlier, were T-quizzes, reviews, and final examination. Inspection of the table above shows no statistically significant differences on any of these criteria.

Some of the results shown above were checked against results obtained from the symmetrically balanced groups taught by instructors A, B, and C. It may be recalled that each of these instructors had been assigned once to each of the three treatments. The results are shown in Table 6.

TABLE 6. DISTRIBUTION OF MEDIAN SCORES IN SYMMETRICALLY BALANCED GROUPS

<u>Instrument</u>	<u>Tr. I</u>	<u>Tr. II</u>	<u>Tr. III</u>	<u>p</u>
6-wk. average	3.42	3.38	3.33	.10 < p < .20
12-wk. daily work grade	3.47	3.43	3.34	.001 < p < .01
12-wk. average	3.41	3.33	3.34	.20 < p < .30
Reviews	3.45	3.39	3.47	.80 < p < .90

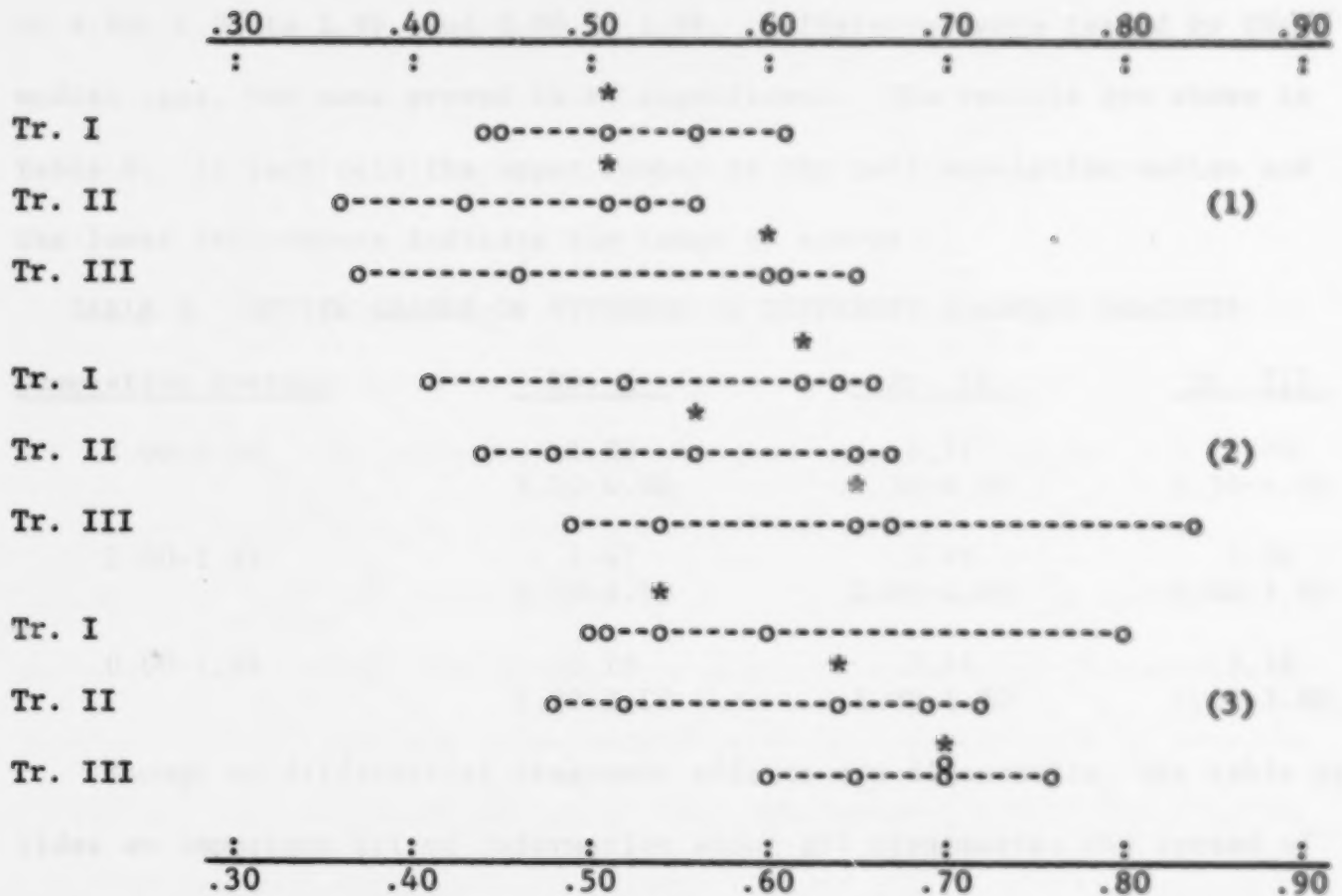
The only differences of statistical significance are between medians of the daily work grades. This, however, is of doubtful validity as a criterion of performance inasmuch as during daily work the student is permitted to seek help from the instructor, from fellow students, from the text, and from lecture notes.

Relation of Treatments to Academic Abilities

A point of interest is one of extent to which grading under various treatments corresponded to the students' total academic abilities. Cumulative averages in all courses taken by the student during the year were used as indices of the latter, and rank-order coefficients of correlation were calculated between these and measures regarded as most valid: T-quizzes after 6 weeks, T-quizzes after 12 weeks, and review grades. The final examination scores were not used because of the restricted nature of the population, the better students having been exempted.

The coefficients were calculated independently for each group, and the results are shown graphically in Table 7. Inasmuch as there were 15 groups, 5 coefficients were available for each treatment. These are shown in the table as small circles, the median coefficient of each treatment being identified by an asterisk.

TABLE 7. RANK-ORDER COEFFICIENTS OF CORRELATION BETWEEN CUMULATIVE ACADEMIC AVERAGES AND THE FOLLOWING MEASURES: (1) AVERAGE OF T-QUIZZES TAKEN DURING THE FIRST 6-WEEK PERIOD; (2) AVERAGE OF T-QUIZZES TAKEN DURING THE ENTIRE 12-WEEK PERIOD; AND (3) REVIEW GRADES



A visual inspection of Table 7 reveals two trends: (1) The review grades correspond more closely to the students' abilities than do the T-quiz averages; this finding lends some credence to the assumption of the validity of the review grades as the criterion for measuring the effects of treatments. (2) Grading in Treatment III corresponds more closely to the students' abilities than grading in other treatments. This trend is particularly evident in the review grades. A possible implication of these two trends is that a student has maximal potentiality to demonstrate his ability when he is taught under Treatment III and tested by the series of problems known as the "Review."

Another point of interest is whether the three treatments had differential effect on students of different abilities. To test this, review medians were calculated for students in three different cumulative average ranges: 3.00 to 4.00, 2.00 to 2.99, and 0.00 to 1.99. Differences were tested by the median test, but none proved to be significant. The results are shown in Table 8. In each cell the upper number is the cell population median and the lower two numbers indicate the range of scores.

TABLE 8. REVIEW GRADES OF STUDENTS IN DIFFERENT ACADEMIC BRACKETS

<u>Cumulative Average</u>	<u>Tr. I</u>	<u>Tr. II</u>	<u>Tr. III</u>
3.00-4.00	3.72 3.10-4.00	3.77 3.30-4.00	3.80 3.30-4.00
2.00-2.99	3.47 2.70-3.90	3.49 2.60-4.00	3.54 2.60-3.90
0.00-1.99	3.15 1.00-3.80	3.16 1.00-3.80	3.16 1.00-3.80

Though no differential treatment effects are discernible, the table provides an important bit of information about all treatments: the spread of grades is much higher among students of lower ability than it is among students of higher ability. The implication of this observation is discussed under "Conclusions."

Student Reactions to the Experiment

A factor that may have confounded the effects of treatments was lack of control over the students' behavior outside of formal class sessions. To gauge this, as well as to evaluate the students' reactions to the various methods of instruction, an anonymous questionnaire was administered at the end of the term. This is attached as Appendix A. The questionnaire was completed and returned by approximately 90 per cent of the students.

As a test of the veracity of students' answers to the questionnaire, the students were asked to report their grade at the end of 12 weeks.

These were letter grades A, B, C, D, and F, and their frequency distribution was compared by the chi-square method with the known distribution in the faculty records. The p value obtained was sufficiently large to justify attributing any discrepancies to chance factors. Though the test is not a certain guarantee against falsification on other items, it does nothing to warrant rejection of the assumption of accuracy and veracity in the students' reports.

A possible confounding factor that emerged from the questionnaire is the large number of students who studied texts used in other than their own treatments. The percentages of students in each treatment who delved into texts other than the assigned were: Treatment I - 53 per cent, Treatment II - 18 per cent, Treatment III - 11 per cent. To test the extent of confounding, the 12-week averages of students in Treatment I who read extraneous texts were compared with 12-week averages of students within the same treatment who read only the assigned text. The results are shown in Table 9.

TABLE 9. DISTRIBUTION OF 12-WEEK AVERAGES AMONG STUDENTS OF DIFFERENT READING HABITS IN TREATMENT I

<u>Reading Habit</u>	<u>12-Week Average Grade</u>		<u>Total</u>
	<u>A or B</u>	<u>C, D, or F</u>	
Own plus other texts	63%	37%	100%
Own text only	74%	26%	100%

The preponderance of high grades among students who read only the assigned texts warrants rejection of any assumption of confounding due to extraneous reading.

Analysis of other items in the questionnaire yielded only three significant differences. These are:

1. Higher degree of preference for text used in Treatments II and III.
2. Higher degree of preference for lectures in Treatment I, and

3. Higher degree of satisfaction with the method of grading in Treatment I.

The results are shown in Table 10. The cell values are percentages of the column totals for each item.

TABLE 10. DISTRIBUTION OF ANSWERS TO SELECTED ITEMS ON THE STUDENT QUESTIONNAIRE

<u>Option</u>	<u>Tr. I</u>	<u>Tr. II</u>	<u>Tr. III</u>	<u>P</u>
TEXT:				
Excellent	9	10	15	p < .001
Good	40	63	59	
Fair	37½	19	21½	
Poor	17½	8	4½	
LECTURES:				
Excellent	41	21	16	p < .001
Good	45½	52	57	
Fair	11½	19	21	
Poor	2	8	6	
GRADING:				
Very fair	41	26	33	.01 < p < .02
Adequate	40	42	43	
Somewhat unfair	16	26	19	
Poor	3	6	5	

CONCLUSIONS

In the over-all analysis, no significant differences are clearly discernible among the effects of the three treatments. Although it may be justifiably inferred that the three treatments are equally effective, another possible interpretation is that the differential effectiveness of the treatments may have been obscured by one or more of the following factors:

1. Reduction in the lecture time in Treatment III. The plausibility of this interpretation is indicated by the somewhat less enthusiastic student reactions to lectures in that treatment. Also, the observation that the curtailed lectures did not affect the students' performance may be an indication of the efficacy of the method used in Treatment III.
2. Somewhat lesser demand in daily work upon students in Treatment I. The plausibility of this interpretation stems logically from the fact that Treatment I did not require pictorial representation, whereas the other two treatments did.
3. Greater demand for instructor's help in Treatment I than in the other treatments. Although no direct evidence for this is available, two sources of data indicate the plausibility of this interpretation: (a) superior performance of students in Treatment I on daily work, and (b) expressed dissatisfaction with the text as source of help and information.
4. Greater opportunity in Treatment I to obtain assistance from other students on daily work. This inference stems logically from the physical arrangement of drawing tables. In the classroom used for Treatments II and III, aisles separated individual tables; in the room used for Treatment I, aisles separated pairs of adjacent tables.
5. More intensive preparation by the instructor for Treatment I. This, again, is a logical inference, stemming from the fact that the text was new, and the material, though within the scope of knowledge of the faculty, was to be presented in a manner somewhat different from the standard practice of previous years. Indirect evidence for the inference is provided by the students' favorable reaction to lectures in Treatment I.
6. Insensitivity of the course requirements as evaluating instruments. The plausibility of this interpretation is indicated by the wide spread of grades among students of low ability, with some students of below C cumulative average capable of achieving

a grade as high as 3.8. This wide spread is in sharp contrast to the narrow range of grades among students of higher ability.

With the exception of Item 6, all the factors listed above tend to favor Treatment I. In spite of intensive study of the experimental procedure, no comparable loading factors in favor of other treatments have been found. If the plausibility of the above factors is admitted, it should be surprising that student performance in Treatment I was not significantly better than performance in the other treatments, unless, of course, one is prepared to acknowledge the superiority of the pictorial method over the restricted multi-view projection method. The lack of significant differences in the results does not eliminate this possibility. In the light of the factors listed previously, it indicates additional controls that must be exercised in further study of the problems of educational research in the field of newer media. These are described under "Recommendations."

RECOMMENDATIONS

1. Future research designs should insure that the use of newer educational media does not interfere with the adequate coverage of material in the lecture. In the present experiment, the film was not exclusively an expository instrument: its function was not only to teach but also to arouse interest. Accordingly, it may not be regarded as a direct substitute for the equivalent lecture time. One possible procedure is to introduce films in the drawing laboratory, at the expense of some daily work; another possibility is to show films outside the normal class requirements.
2. The daily work requirements in all treatments should be made equal. If a requirement, such as pictorial representation, is withdrawn from a treatment for the purpose of the experiment, some additional demands should be imposed on the groups within that treatment.
3. Instructors should pay active attention in all treatments to the students' daily work, with particular alertness to students who need but do not seek help. Reluctance to seek help may very easily stem from the student's assumption that his particular text is a complete source of information. Such is not always the case.
4. The physical arrangement of classroom equipment should be identical in all treatments. Identity is, of course, impossible to achieve; it may, however, be approached by elimination of features that obviously favor one treatment over others.
5. Maximum effort by instructors in the preparation of lectures should be assured. This recommendation is particularly pertinent to instructors who use a familiar text and notes, where dependence on memory may affect adversely consideration of some important details. A weekly briefing of the faculty on systematic presentation of the current topics should contribute to uniformity in the quality of lectures.
6. Over-all course requirements should be as rigorous as possible, in the interest of greater sensitivity of the evaluating instruments. This should lead to better discrimination among students in higher academic brackets. Ideally, the increase in course demands should be of such magnitude as to equalize variances in all academic brackets.

Any experimental design is bound to contain variables that had not been accounted for, and variables that could not have been anticipated. The recommendations listed previously stem from post hoc observation of such types of variables. Control of these might well have led to different results. Discovery of these is a lesson for the future.

The creation and use of animated films had as its purpose the inclusion of teaching material which, it was hoped, would arouse in the student an extra "feel" for the consideration of spatial relationships; however, this material may really be "passive," in that the student was not actually forced to accept it. It was also hoped that the inclusion of this added stimulus might be reflected statistically in the evaluation of the performances of the various groups. It seems logical to assume that those who were supplied with this aid, and accepted it, and those who were required to practice pictorial expression, and did so, benefited thereby. Therefore, as implied previously, similar studies in the future should include more sensitive measurements of achievement. These might include a six-months' retention test, and some over-all spatial achievement testing independent of the contents of the specific course material.

It should be recognized that, in this investigation as in many others, the search was for better methods of implementing the transmitting part of the communication process. It may be that future investigations should concentrate on the process of motivating students to receive information via newer media, with the purpose of discovering means by which students' efficiency of thought and action in the learning process can be improved.

Although derived from a particular study, these recommendations and comments are believed to have universality and are listed here in the hope of their being a modest contribution to rigor and precision in educational research.

STUDENT QUESTIONNAIRE

Please state your frank opinions about the following topics by check marks in the appropriate spaces. DO NOT WRITE YOUR NAME.

TEXTBOOK: Excellent _____ Good _____ Fair _____ Poor _____

INSTRUCTOR: Excellent _____ Good _____ Fair _____ Poor _____

PLANS, if you have seen them: Very helpful _____ Somewhat helpful _____ Little help _____ No help _____

AMOUNT OF WORK FOR PERIOD: Burdensome _____ Heavy _____ Light _____ Minimal _____

METHOD OF GRADING: Very fair _____ Fair _____ Somewhat fair _____ Poor _____

INSTRUCTOR'S SE-
RVICE INSTRUCTION
AND QUIZZES: Very good _____ Good _____ Fair _____ Poor _____

APPENDIX A

STUDENT QUESTIONNAIRE

INSTRUCTIONAL VALUE OF PLANS: Very helpful _____ Somewhat helpful _____ Little help _____ No help _____

INSTRUCTIONAL VALUE OF DAILY DRAMAS: Very helpful _____ Somewhat helpful _____ Little help _____ No help _____

INSTRUCTIONAL VALUE OF PICTORIAL METHOD, if you had it: Very helpful _____ Somewhat helpful _____ Little help _____ No help _____

VALUE OF THE COURSE TO YOUR PROFESSION: Very helpful _____ Somewhat helpful _____ Little help _____ No help _____

What is your major field? _____

What is your text? _____ Have you seen films? _____

Have you read texts other than the assigned text? _____

If yes, what have you read? _____

Have you studied outside the class? _____ How many hours a week? _____

When does your class meet? 7th am _____ 11th pm _____ 1st pm _____ 4th am _____

In what room? 1st _____ 17-B _____ 17-A _____

What is your "Advance" grade? _____

PLEASE WRITE ADDITIONAL COMMENTS YOU MAY WISH TO MAKE ON THE BACK OF THIS SHEET.

STUDENT QUESTIONNAIRE

Please state your frank opinions about the following topics by check marks in the appropriate spaces. DO NOT WRITE YOUR NAME.

TEXTBOOK:	Excellent	Good	Fair	Poor
	___	___	___	___
LECTURES:	Excellent	Good	Fair	Poor
	___	___	___	___
FILMS, if you have seen them:	Very helpful	Some help	Little help	Use- less
	___	___	___	___
AMOUNT OF WORK PER PERIOD:	Excessive	A bit heavy	A bit light	Too little
	___	___	___	___
METHOD OF GRADING:	Very fair	Adequate	Somewhat unfair	Poor
	___	___	___	___
CORRESPONDENCE BE- TWEEN INSTRUCTION AND QUIZZES:	Very good	Adequate	Inade- quate	None
	___	___	___	___
INSTRUCTIONAL VALUE OF PLATES:	Very helpful	Some help	Little help	Of no value
	___	___	___	___
INSTRUCTIONAL VALUE OF DAILY DRAWINGS:	Very helpful	Some help	Little help	Of no value
	___	___	___	___
INSTRUCTIONAL VALUE OF PICTORIAL METHOD, if you had it:	Very helpful	Some help	Little help	Of no value
	___	___	___	___
VALUE OF THE COURSE TO YOUR PROFESSION:	Very helpful	Some help	Little help	Of no value
	___	___	___	___

What is your major field? _____

What is your text? _____ Have you seen films? _____

Have you read texts other than the assigned text? _____

If yes, what have you read? _____

Have you studied outside the class? _____ How many hours a week? _____

When does your class meet? TTh am _____ TTh pm _____ MW pm _____ WF am _____

In what room? 16 _____ 17-N _____ 17-S _____

What is your "Advance" grade? _____

PLEASE WRITE ADDITIONAL COMMENTS YOU MAY WISH TO MAKE ON THE BACK OF THIS SHEET.



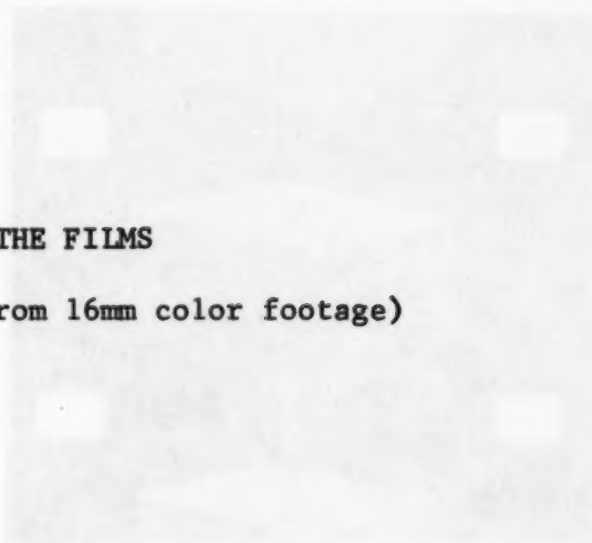
INTRODUCTION TO SPATIAL CONCEPTS

A summary from showing fundamental spatial forms. These were individually generated, using colored models and special effects photography.

APPENDIX B

SAMPLE FRAMES FROM THE FILMS

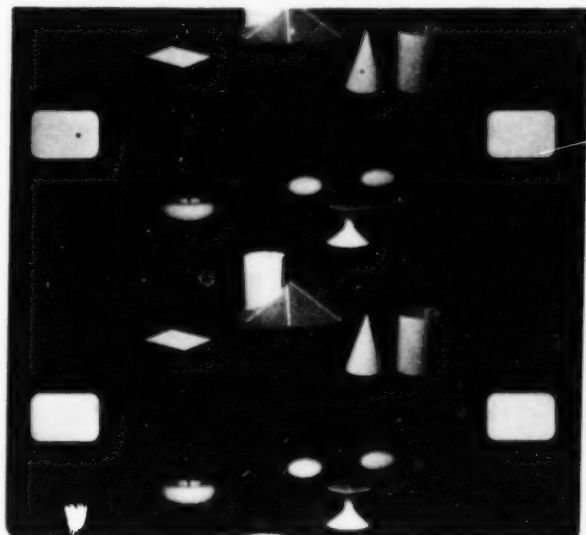
(Reproduced in black and white from 16mm color footage)



LINE AND PLANE SPATIALITY PART I

Part of a sequence illustrating the spatial concepts of line and plane.

Showing how these concepts relate to the spatial concepts of line and plane.



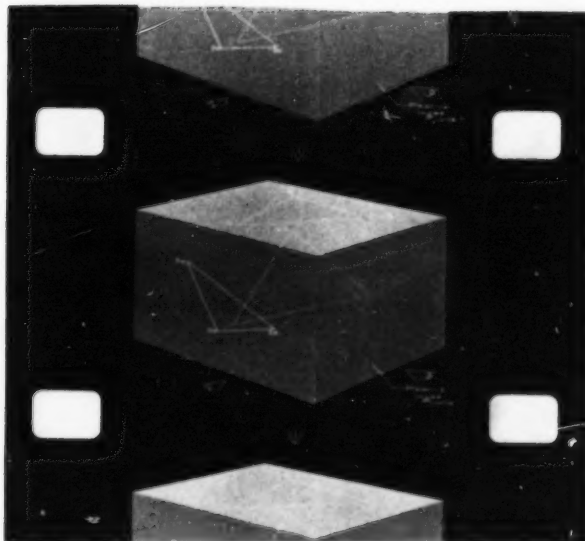
INTRODUCTION TO SPATIAL CONCEPTS

A summary frame showing fundamental spatial forms. These were individually generated, using animated models and special effects photography.

PLANES

From a sequence illustrating the recording of a triangle on the image planes.

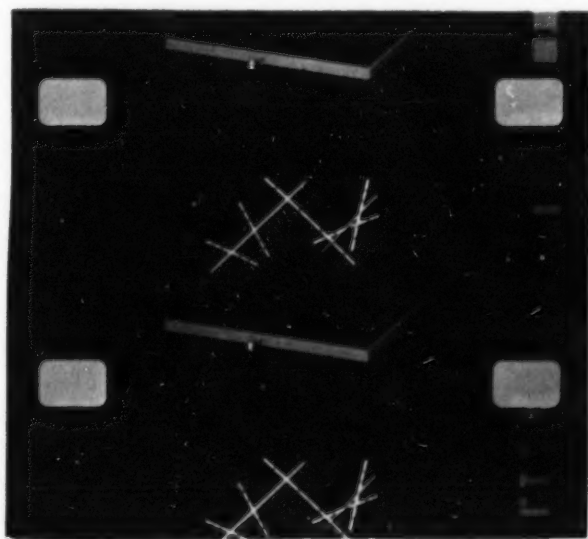
The planes and projected images were developed using techniques of color separation, uncovering hidden lines, and multiple exposure.

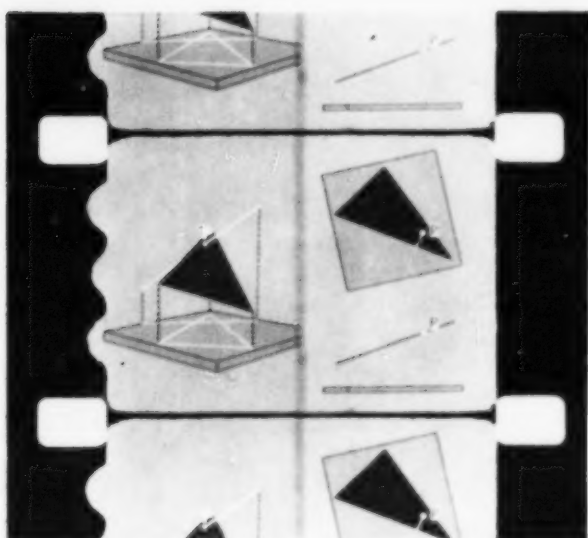


LINE AND PLANE RELATIONSHIPS PART I

Part of a sequence illustrating the shortest connection between two oblique lines.

Filming was done using models with removable and movable parts photographed under ultra-violet light.





LINE AND PLANE RELATIONSHIPS PART II

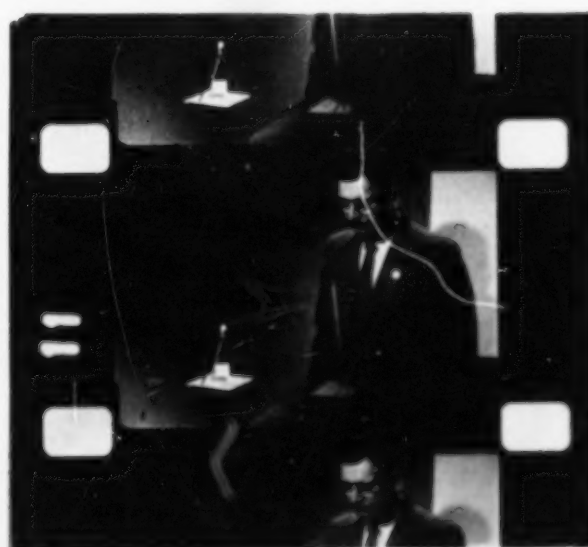
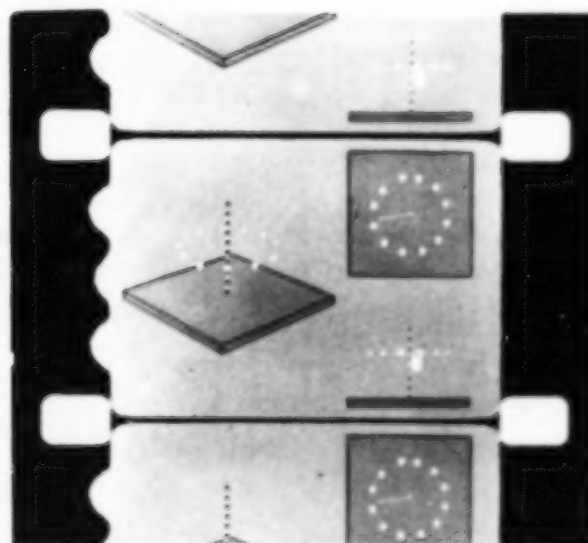
A combination of the pictorial representation and the multi-view projections of a line piercing a plane.

Split-screen techniques were used so that visual changes could be presented in relative sequential steps.

REVOLUTIONS

In the film's opening sequence, a point rotates about an axis, emphasizing the basic principle of all revolution.

Limited cell animation and a single-frame camera technique was employed.



VECTORS

A frame from the sequence dealing with the solution of three-dimensional problems using space vectors.

Live action combined with the manipulation of models was a principal technique in producing this film.

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APPENDIX C

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- * Harold G. Elmer, Associate Professor of Engineering Drawing.
- * William F. Bain, Assistant Professor of Engineering Drawing.

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 - * Harold G. Kinner, Associate Professor of Engineering Drawing,
 - * William F. Helm, Assistant Professor of Engineering Drawing,

- * William L. Nelson, Assistant Professor of Engineering Drawing, and
- * Thomas F. MacLaughlin, Instructor in Engineering Drawing.